Microsecond Pulsed Glow Discharge Spectrometry

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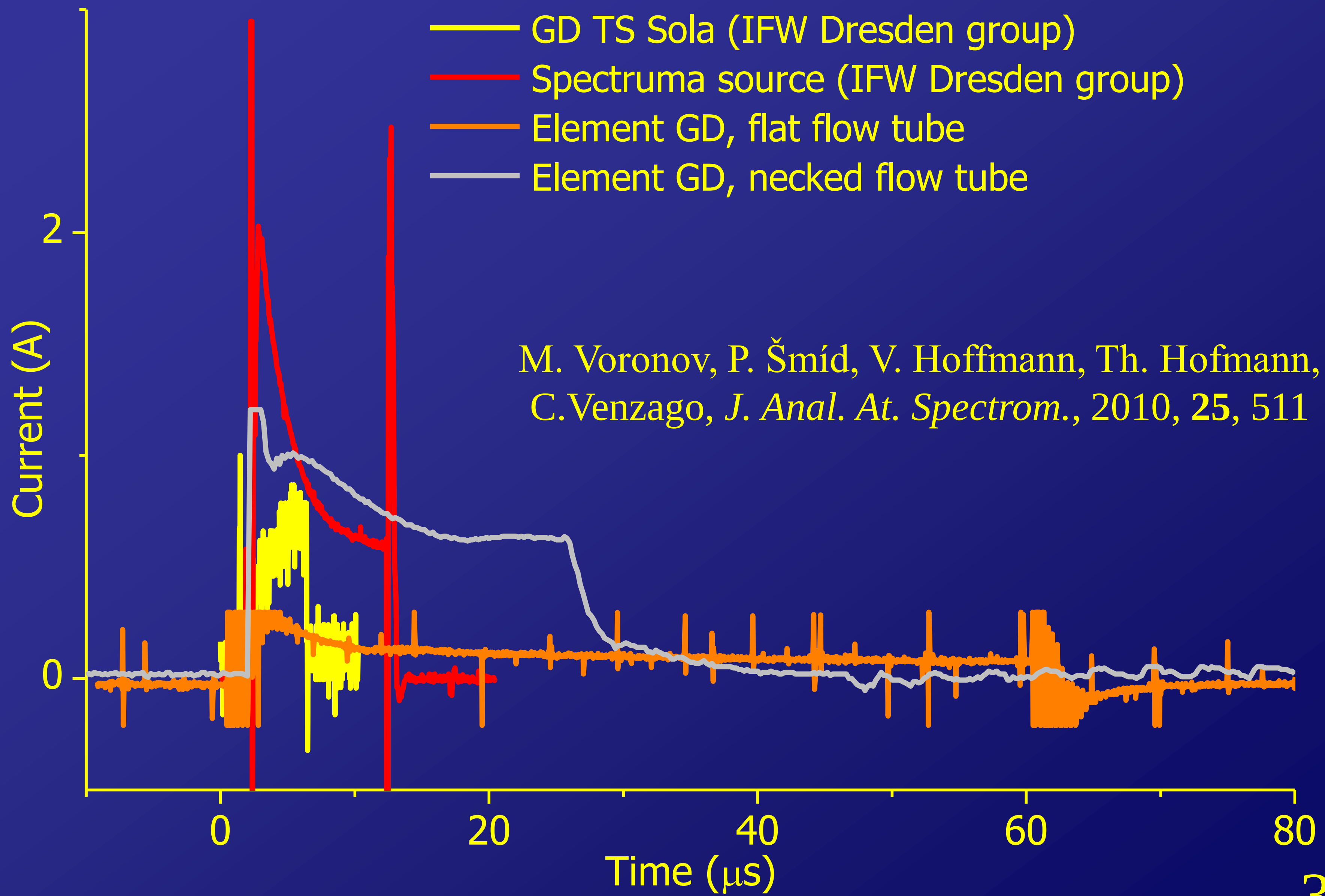
„Analytische Glimmentladungs-Spektrometrie“
24.-25. April 2013
Duisburg

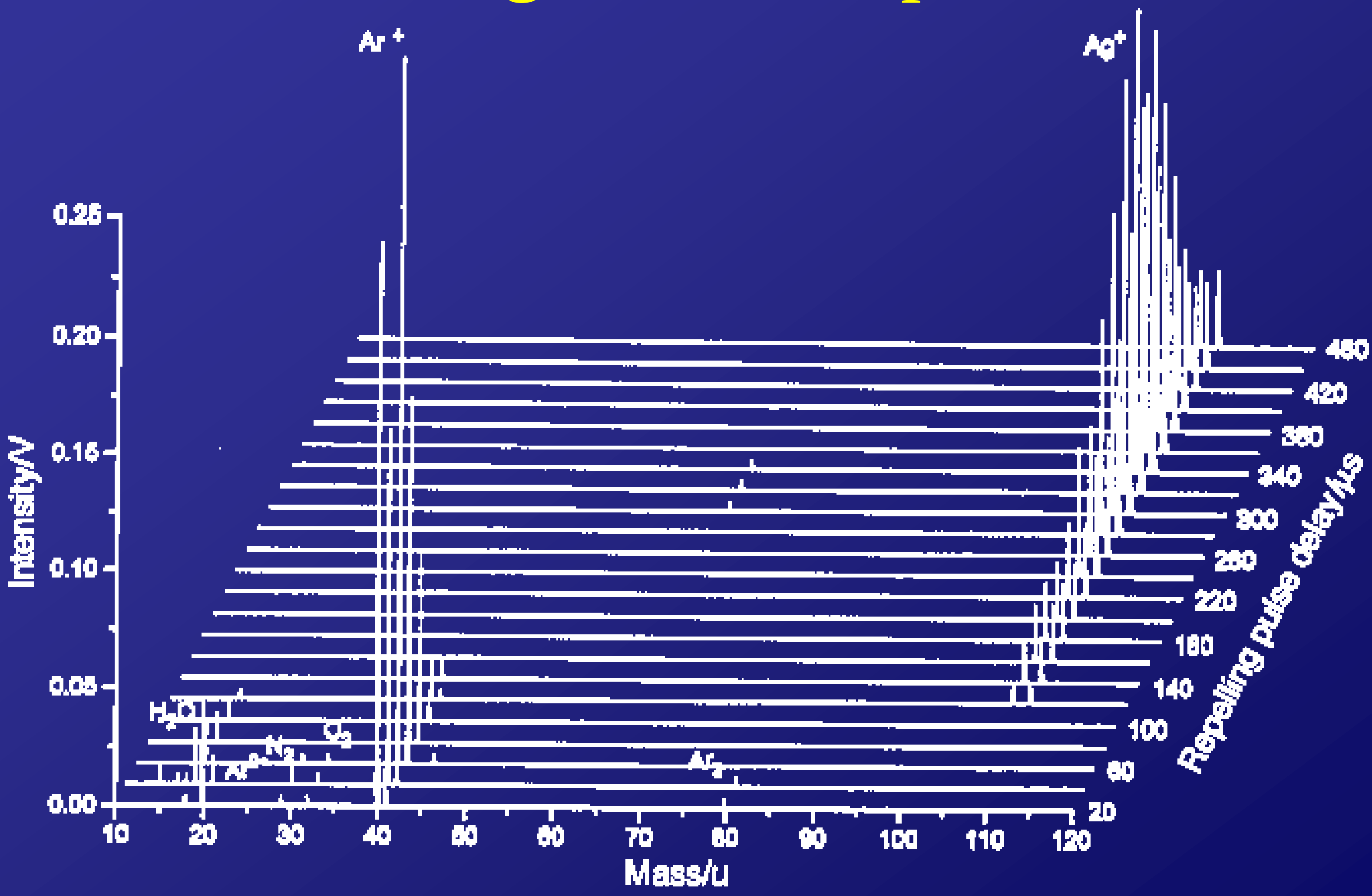
- PGD applications
- Electrical current prepeak
- Plasma emission prepeak

PGD applications



M. Voronov, P. Šmíd, V. Hoffmann, Th. Hofmann, C.Venzago, *J. Anal. At. Spectrom.*, 2010, **25**, 511

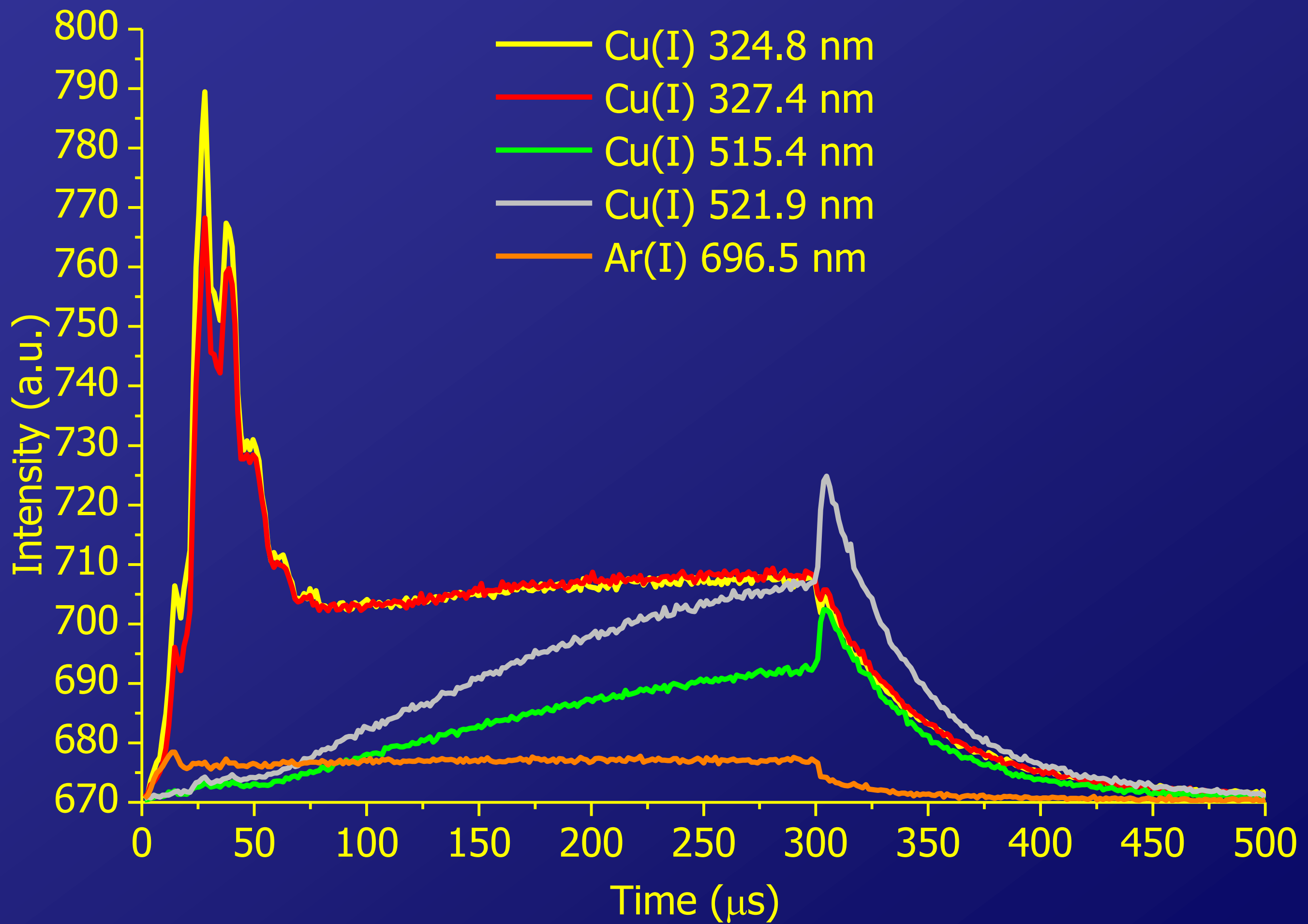
MS: afterglow and separation



W.W. Harrison, W. Hang, X. Yan, K. Ingeneri, C. Schilling, *J. Anal. At. Spectrom.*, 1997, **12**, 893

Radiation prepeak and afterpeak

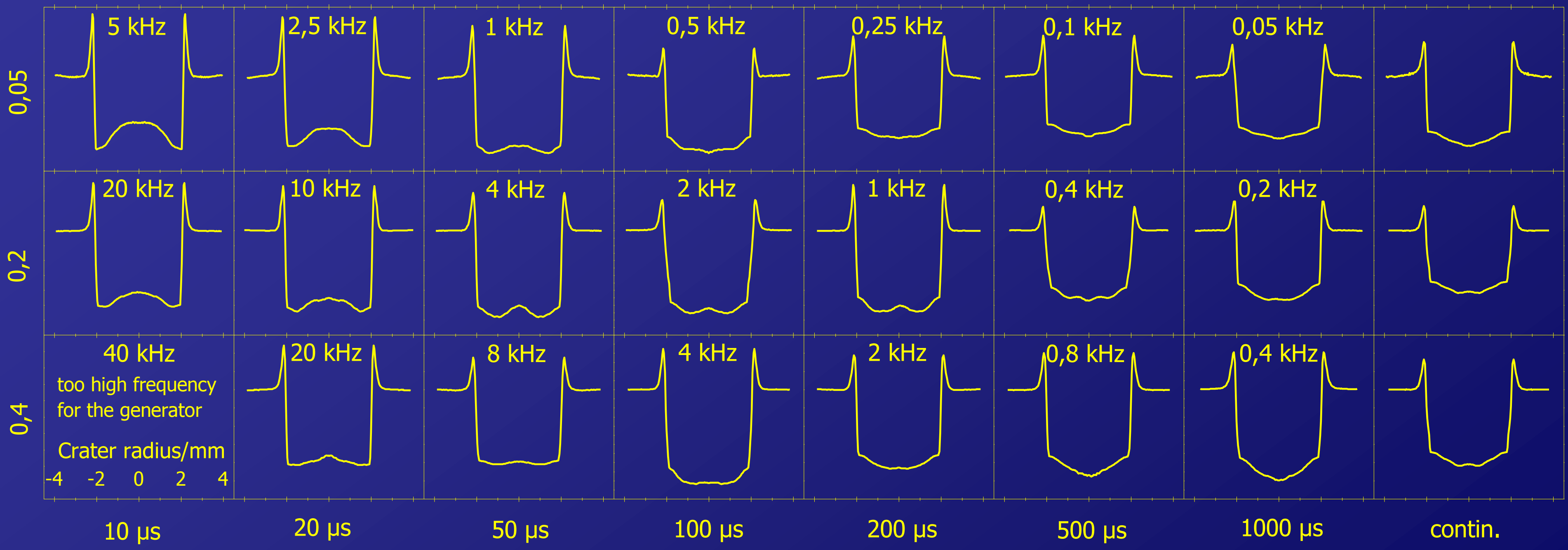
8-mm Grimm type source
rf 2.24 MHz
τ=300 μs
F=350 Hz
p=12 hPa



M. Voronov, V. Hoffmann, T. Wallendorf, S. Marke, J. Mönch, C. Engelhard, W. Buscher, S.J. Ray, G.M. Hieftje, *J. Anal. At. Spectrom.*, 2012, **27**, 419

PGD applications

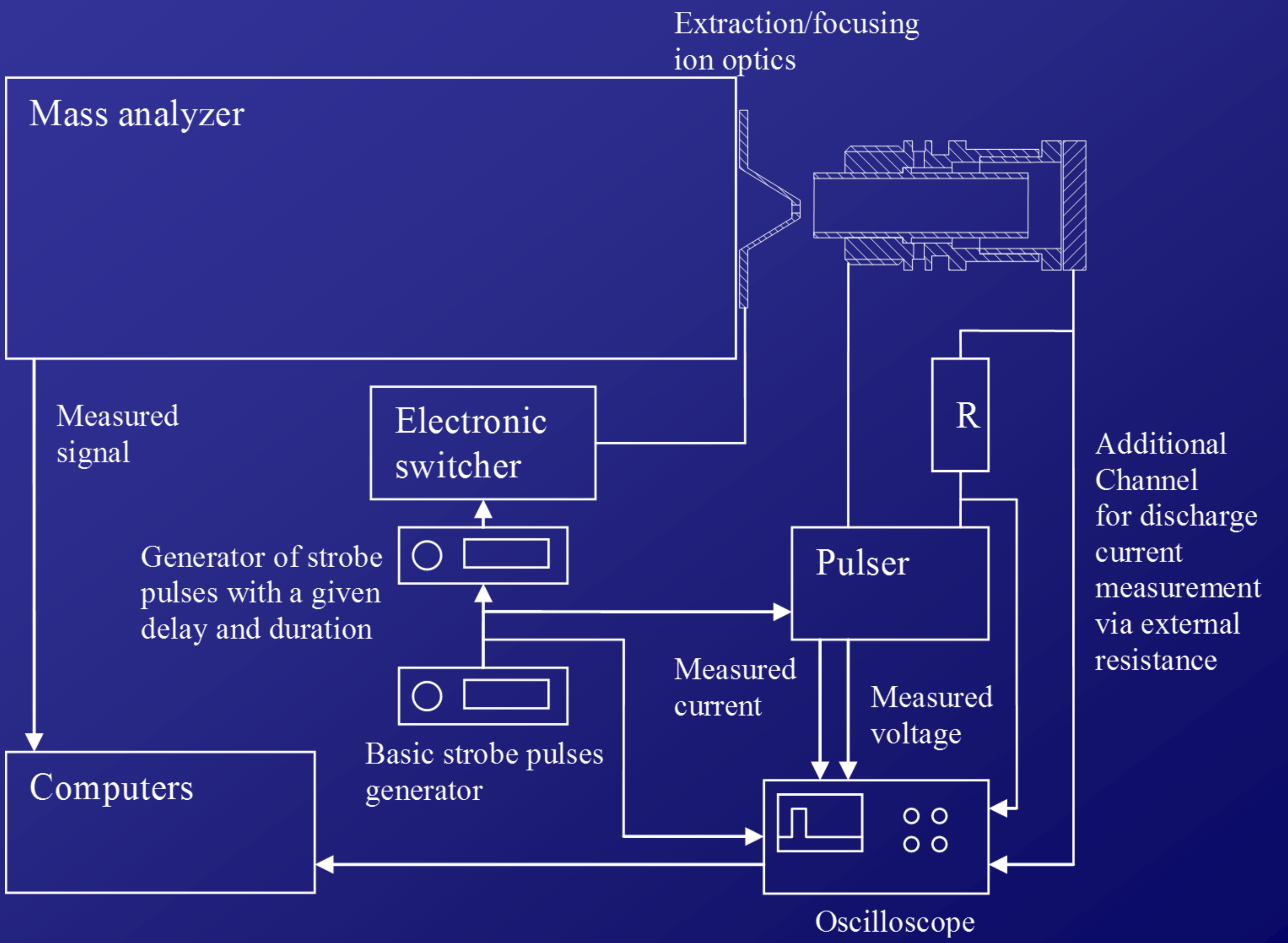
Shapes of craters in Cu samples sputtered with pulsed dc discharge at three different duty cycles (0.05, 0.2 and 0.4) and various pulse lengths (10–1000 μs) (800 V, 7 hPa).



V. Efimova, V. Hoffmann, J. Eckert, *Spectrochmimca Acte part B*, 2012, **76**, 181

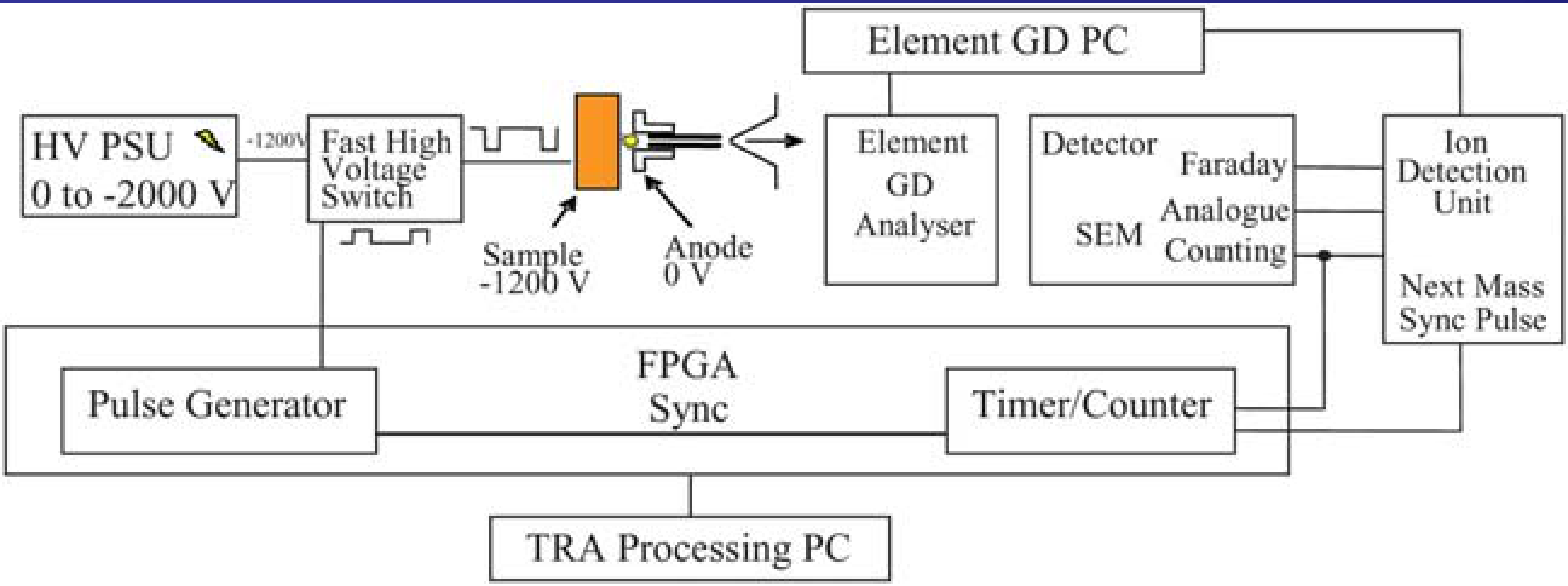
PGD applications: commercial applications

M. Voronov, P. Šmíd, V. Hoffmann, Th. Hofmann, C. Venzago,
J. Anal. At. Spectrom., 2010, **25**, 511



PGD applications: commercial applications

PGD applications: commercial applications

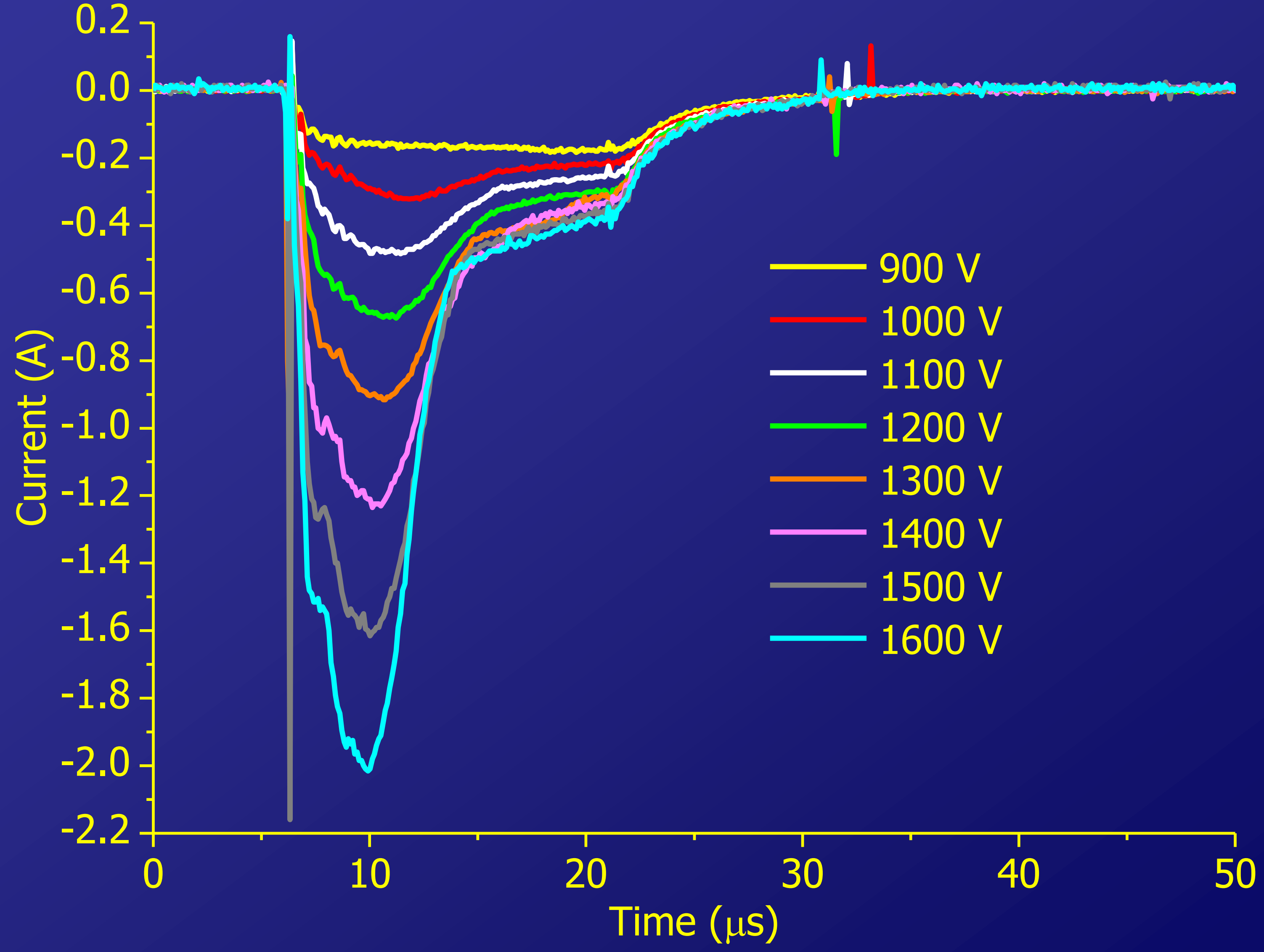


G. Churchill, K. Putyera, V. Weinstein, X. Wang, E.B.M. Steers,
J. Anal. At. Spectrom., 2011, **26**, 2263

- PGD applications
- Electrical current prepeak
- Plasma emission prepeak

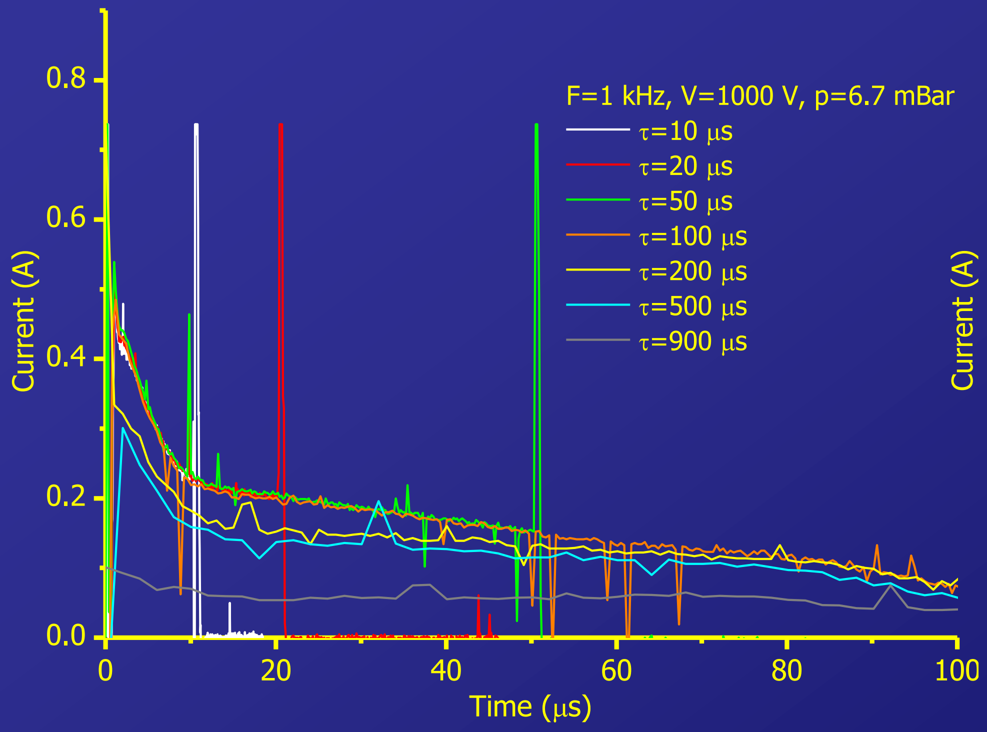
Electrical current prepeak

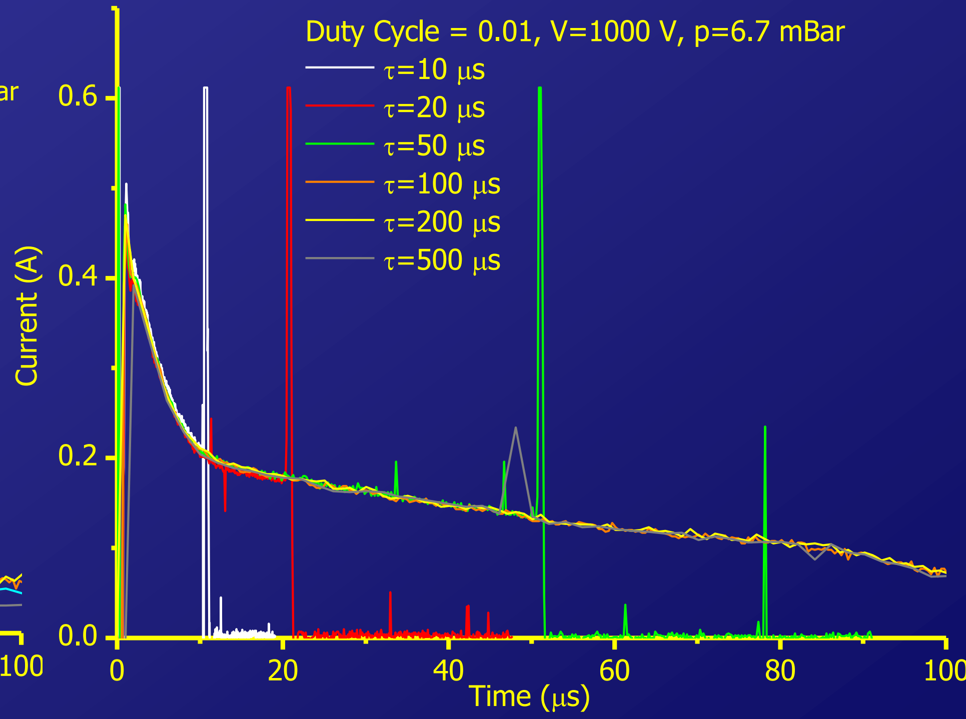
Modified fast flow Grimm type source. Ar flow = 75 sccm, *p* = 2.5 hPa.



Electrical current prepeak

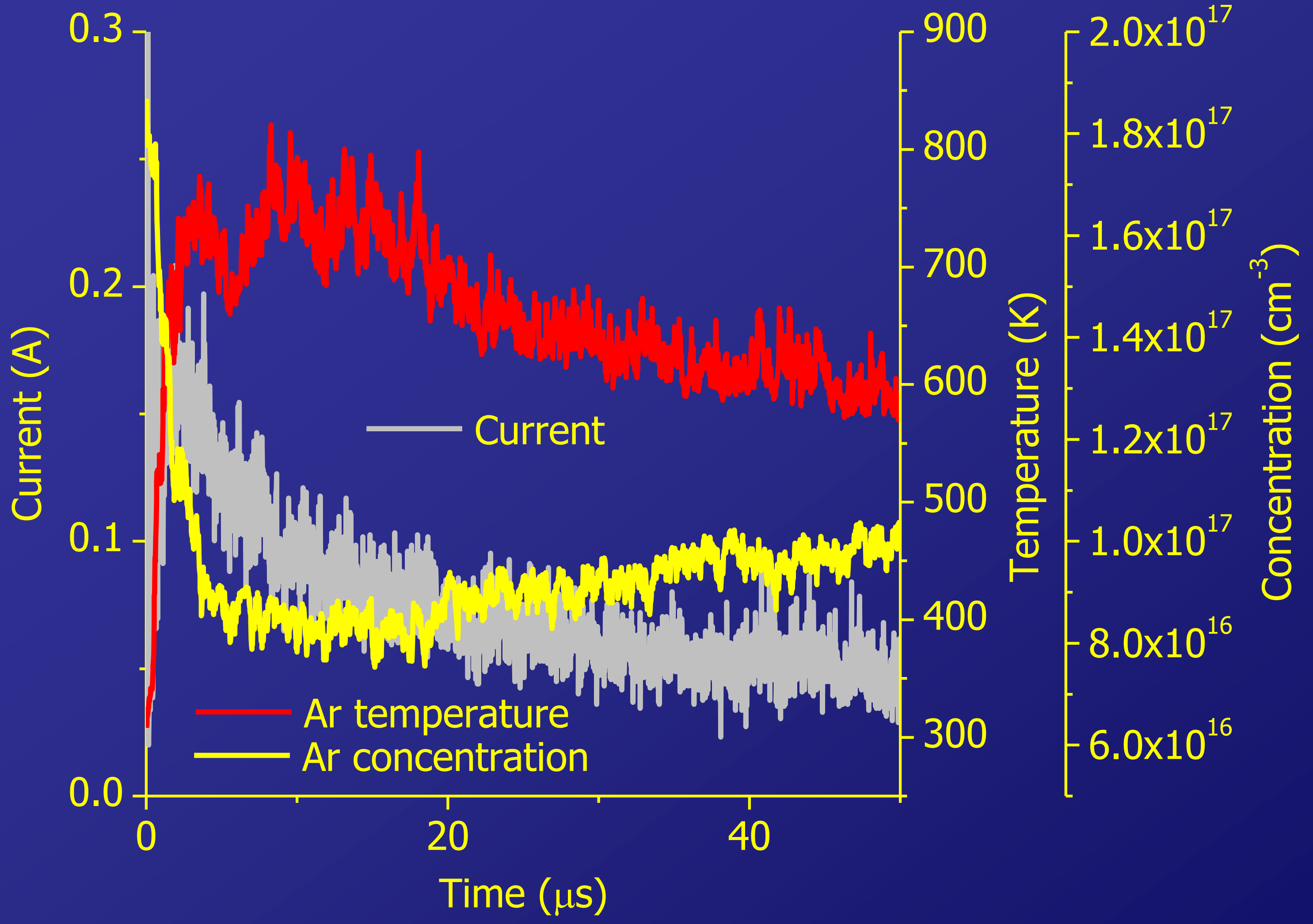
8-mm Grimm type source, *U*=1000 V, *p*=6.7 hPa.





V. Hoffmann, V.V. Efimova, M.V. Voronov, P. Smid, E.B.M. Steers, J. Eckert,
Journal of Physics: Conference Series, 2008, **133**, 012017

Electrical current prepeak: modelling results

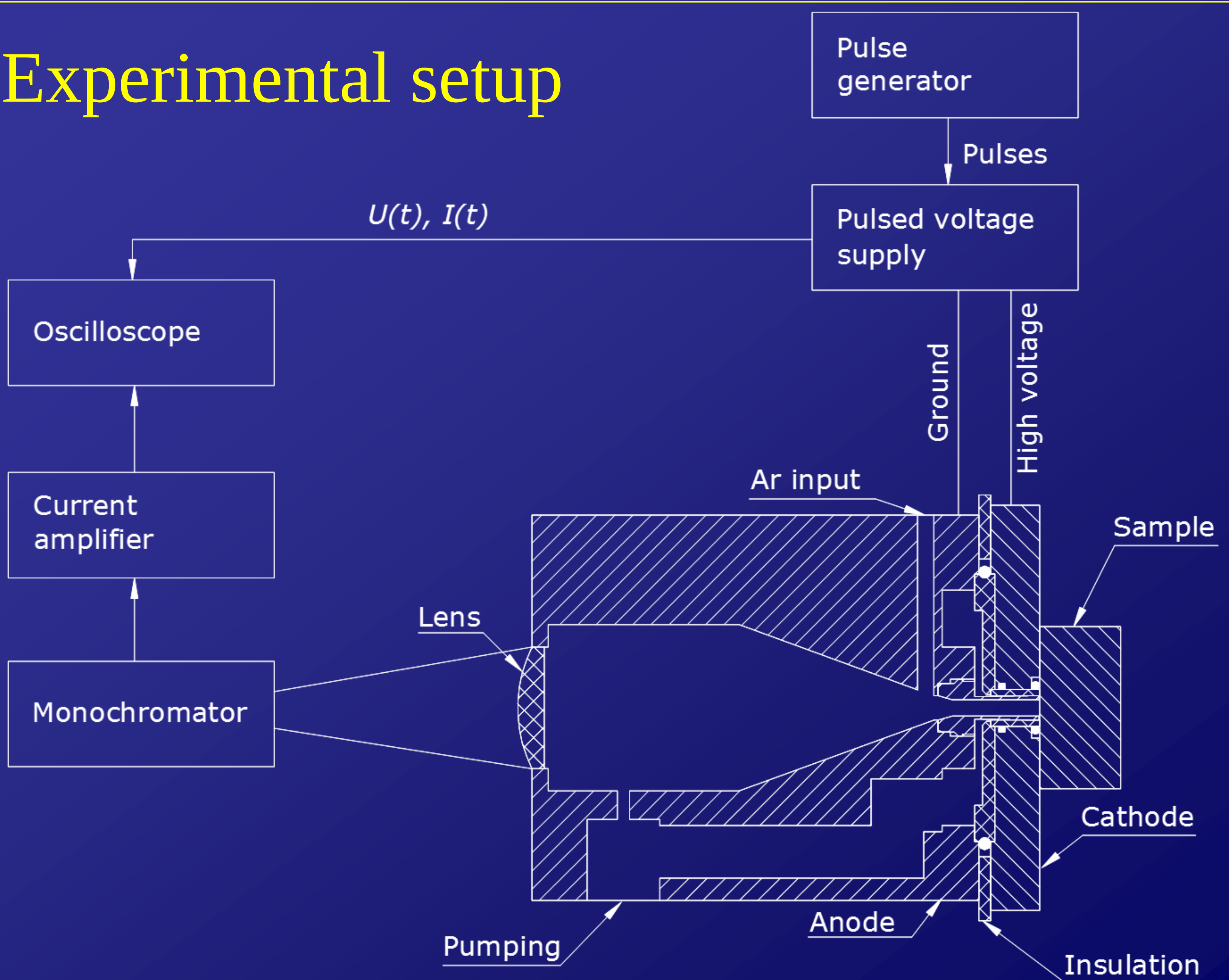


4-mm Grimm type source, *U*=1500 V, *p*=8 hPa.

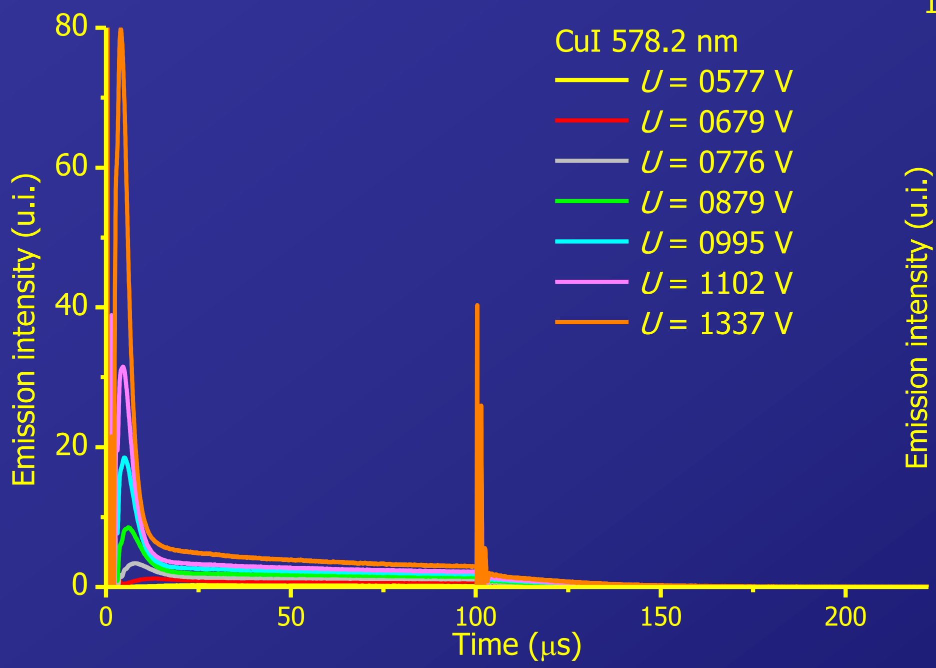
M. Voronov, V. Hoffmann, W. Buscher, C. Engelhard, S.J. Ray, G.M. Hieftje, *J. Anal. At. Spectrom.*, 2012, **27**, 1225

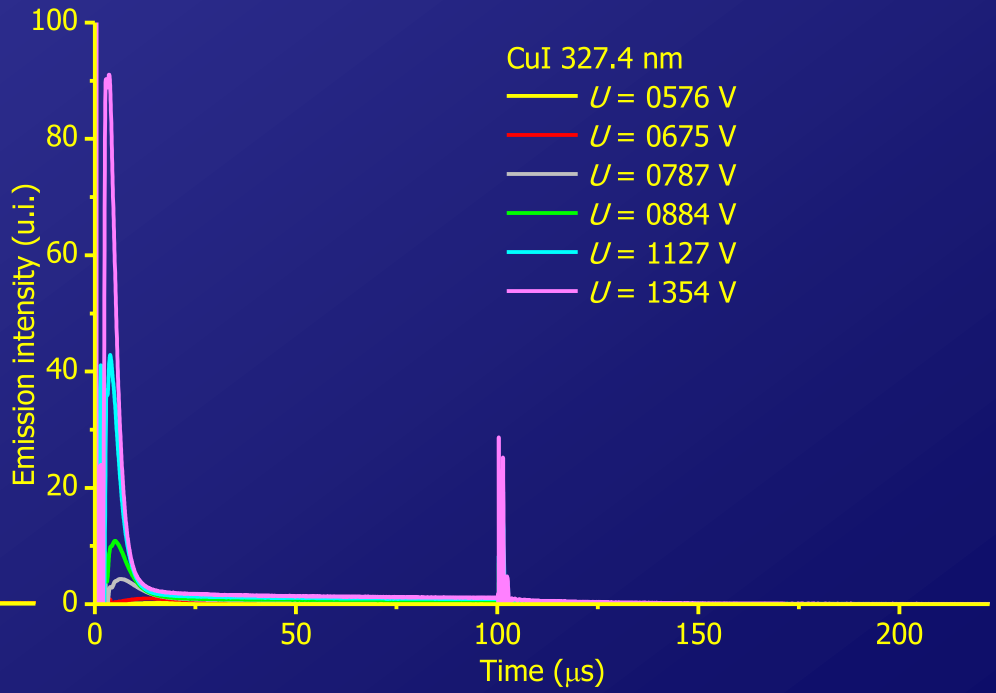
- PGD applications
- Electrical current prepeak
- Plasma emission prepeak

Experimental setup



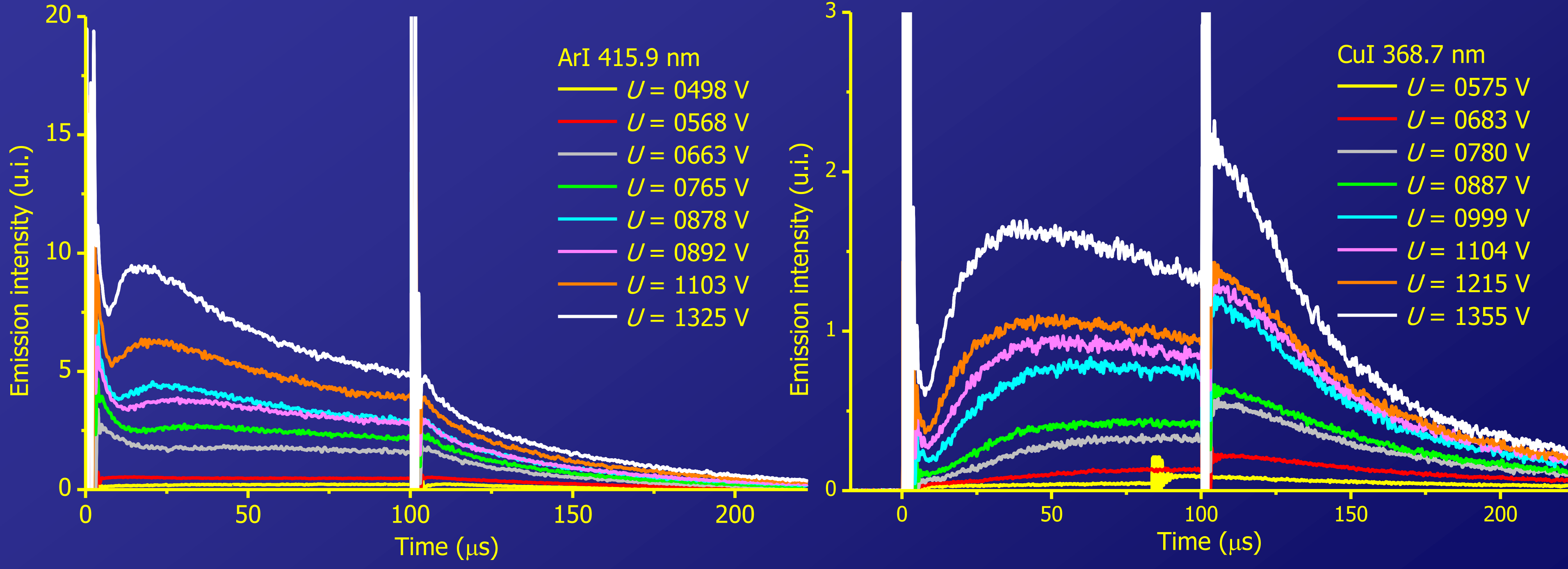
Strong prepeak





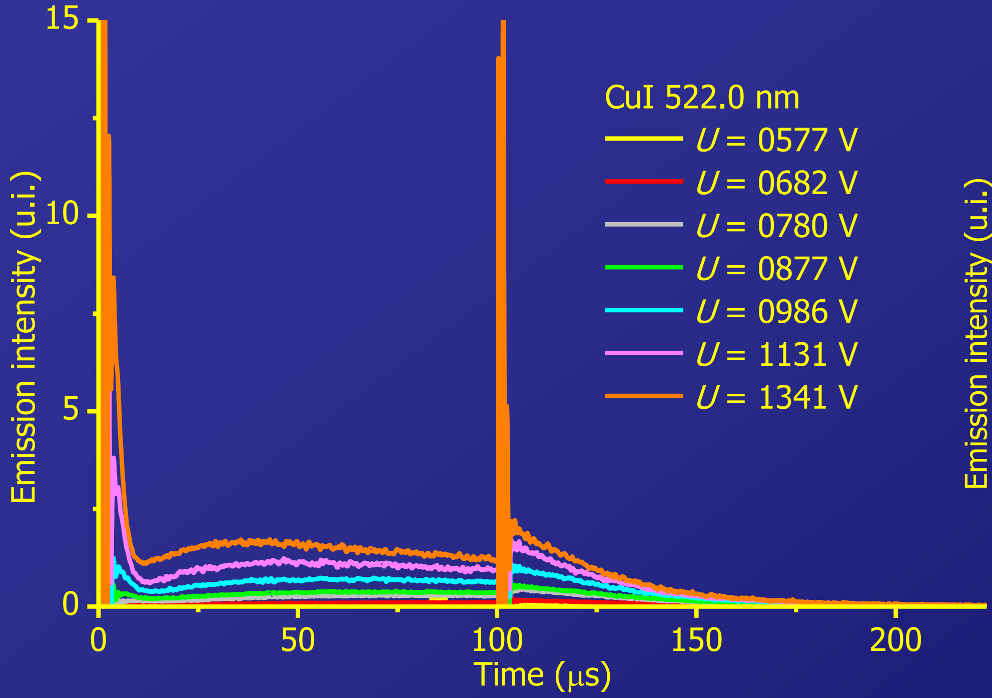
4-mm Grimm type source, *p*=6 hPa, τ=100 μs, *F*=200 Hz

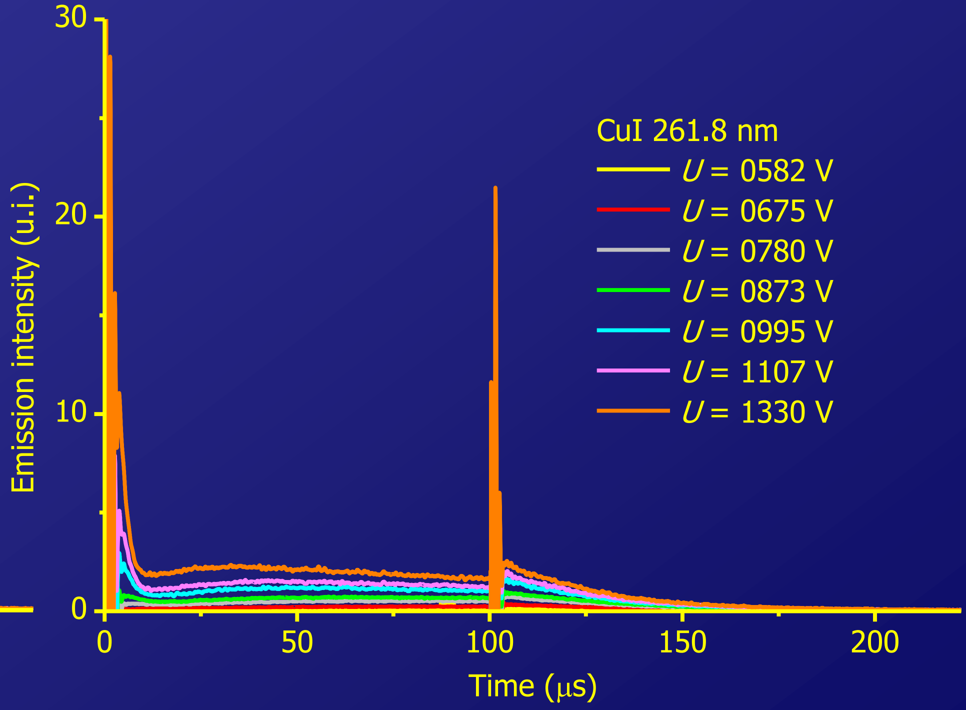
2 prepeaks



4-mm Grimm type source, *p*=6 hPa, *τ*=100 µs, *F*=200 Hz

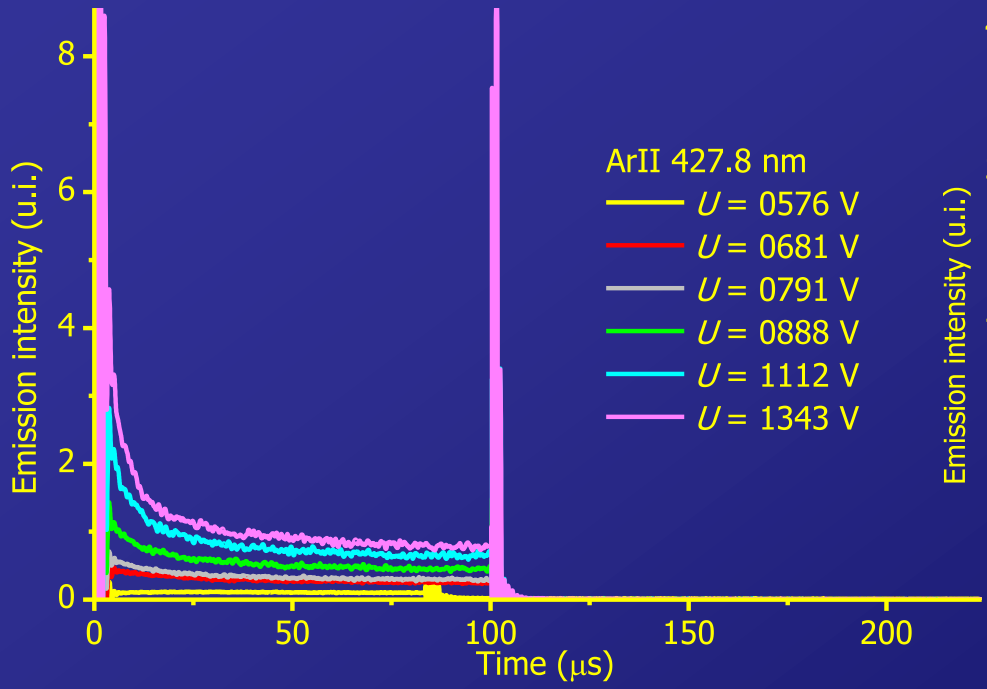
2 prepeaks, the 1st one is strong

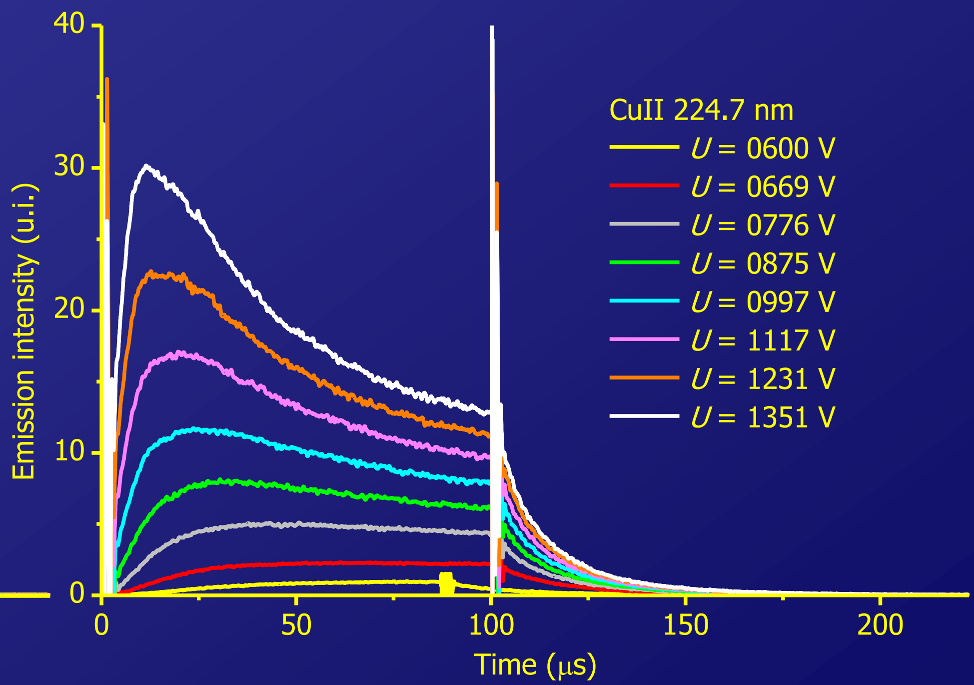




4-mm Grimm type source, p=6 hPa, τ=100 µs, F=200 Hz

Moderate prepeak





4-mm Grimm type source, p=6 hPa, τ=100 μs, F=200 Hz

Plasma emission prepeak

Strong prepeak

2 prepeaks

2 prepeaks, the 1st one is strong

Moderate prepeak

Line	Lower level energy (eV)	Upper level energy (eV)	Lower state	Upper state
Ar I 415.9	11.55	14.53	$3p^5\ (^2P_{3/2})\ 4s\ ^2[3/2]^0_2$	$3p^5\ (^2P^0_{3/2})\ 5p\ ^2[3/2]_2$
Ar I 420.1	11.55	14.50	$3p^5\ (^2P_{3/2})\ 4s\ ^2[3/2]^0_2$	$3p^5\ (^2P^0_{3/2})\ 5p\ ^2[5/2]_3$
Ar I 603.2	13.08	15.13	$3p_5\ (^2P_{3/2})\ 4p\ ^2[5/2]_3$	$3p^5\ (^2P^0_{3/2})\ 5d\ ^2[7/2]^0_4$
Ar I 696.5	11.55	13.33	$3p^5\ (^2P_{3/2})\ 4s\ ^2[3/2]^0_2$	$3p^5\ (^2P^0_{1/2})\ 4p\ ^2[1/2]_1$
Cu I 249.2	0	4.97	$3d^{10}\ (^1S)\ 4s\ ^2S_{1/2}$	$3d^9\ (^2D)\ 4s4p\ (^3P^0)\ ^4P^0_{3/2}$
Cu I 261.8	1.39	6.12	$3d^9\ 4s^2\ ^2D_{5/2}$	$3d^{10}\ (^1S)\ 5p\ ^2P^0_{3/2}$
Cu I 282.4	1.39	5.78	$3d^9\ 4s^2\ ^2D_{5/2}$	$3d^9\ (^2D)\ 4s4p\ (^3P^0)\ ^2D^0_{5/2}$
Cu I 296.1	1.39	5.57	$3d^9\ 4s^2\ ^2D_{5/2}$	$3d^9\ (^2D)\ 4s4p\ (^3P^0)\ ^2F^0_{7/2}$
Cu I 324.7	0	3.82	$3d^{10}\ (^1S)\ 4s\ ^2S_{1/2}$	$3d^{10}\ (^1S)\ 4p\ ^2P^0_{3/2}$
Cu I 327.4	0	3.79	$3d^{10}\ (^1S)\ 4s\ ^2S_{1/2}$	$3d^{10}\ (^1S)\ 4p\ ^2P^0_{1/2}$
Cu I 368.7	3.82	7.18	$3d^{10}\ (^1S)\ 4p\ ^2P^0_{3/2}$	$3d^{10}\ (^1S)\ 6d\ ^2D_{5/2}$
Cu I 465.1	5.07	7.74	$3d^9\ (^2D)\ 4s4p\ (^3P^0)\ ^4F^0_{9/2}$	$3d^9\ 4s\ (^3D)\ 5s\ ^4D_{7/2}$
Cu I 510.6	1.39	3.82	$3d^9\ 4s^2\ ^2D_{5/2}$	$3d^{10}\ (^1S)\ 4p\ ^2P^0_{3/2}$
Cu I 515.3	3.79	6.19	$3d^{10}\ (^1S)\ 4p\ ^2P^0_{1/2}$	$3d^{10}\ (^1S)\ 4d\ ^2D_{3/2}$
Cu I 521.8	3.82	6.19	$3d^{10}\ (^1S)\ 4p\ ^2P^0_{3/2}$	$3d^{10}\ (^1S)\ 4d\ ^2D_{5/2}$
Cu I 522.0	3.82	6.19	$3d^{10}\ (^1S)\ 4p\ ^2P^0_{3/2}$	$3d^{10}\ (^1S)\ 4d\ ^2D_{3/2}$
Cu I 570.0	1.64	3.82	$3d^9\ 4s^2\ ^2D_{3/2}$	$3d^{10}\ (^1S)\ 4p\ ^2P^0_{3/2}$
Cu I 578.2	1.64	3.79	$3d^9\ 4s^2\ ^2D_{3/2}$	$3d^{10}\ (^1S)\ 4p\ ^2P^0_{1/2}$
Ar II 294.3	17.14	21.35	$3s^2\ 3p^4\ (^3P)\ 4s\ ^2P_{3/2}$	$3s^2\ 3p^4\ (^1D)\ 4p\ ^2P^0_{3/2}$
Ar II 329.4	19.87	23.63	$3s^2\ 3p^4\ (^3P)\ 4p\ ^2P^0_{3/2}$	$3s^2\ 3p^4\ (^3P)\ 4d\ ^2P_{3/2}$
Ar II 378.1	19.49	22.77	$3s^2\ 3p^4\ (^3P)\ 4p\ ^4D^0_{7/2}$	$3s^2\ 3p^4\ (^3P)\ 4d\ ^4D_{7/2}$
Ar II 427.8	18.45	21.35	$3s^2\ 3p^4\ (^1D)\ 4s\ ^2D_{5/2}$	$3s^2\ 3p^4\ (^1D)\ 4p\ ^2P^0_{3/2}$
Ar II 434.8	16.64	19.49	$3s^2\ 3p^4\ (^3P)\ 4s\ ^4P_{5/2}$	$3s^2\ 3p^4\ (^3P)\ 4p\ ^4D^0_{7/2}$
Ar II 461.0	18.45	21.14	$3s^2\ 3p^4\ (^1D)\ 4s\ ^2D_{5/2}$	$3s^2\ 3p^4\ (^1D)\ 4p\ ^2F^0_{7/2}$
Ar II 611.5	19.12	21.14	$3s^2\ 3p^4\ (^1D)\ 3d\ ^2G_{9/2}$	$3s^2\ 3p^4\ (^1D)\ 4p\ ^2F^0_{7/2}$
Cu II 224.7	2.72	8.23	$3d^9\ (^2D)\ 4s\ ^3D_3$	$3d^9\ (^2D)\ 4p\ ^3P^0_2$

Summary

- PGD can enhance detected analytical signal and reduce thermal stress of the sample
- Electrical current prepeak is generated by Ar heating and expansion at the leading edge of the discharge
- Plasma emission prepeak exists at all detected lines at high voltage. Profile of the prepeak depends on the transition

Thank you for your attention!